PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2005-075661
(43)Date of publication of application : 24.03.2005

(51)Int.Cl. C01B 31/02

(21)Application number : 2003-305681
(22)Date of filing : 29.08.2003

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(54) CARBON NANOTUBE DISPERSED SOLUTION AND METHOD OF MANUFACTURING THE SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a carbon nanotube dispersed solution comprising carbon nanotube, an amide based polar organic solvent and a nonionic surfactant and a method of manufacturing the same.
SOLUTION: The carbon nanotube is mixed and dispersed in a mixed solution of the amide based organic solvent and the nonionic surfactant while performing ultrasonic treatment. As the amide based organic solvent, any of dimethylformamide (DMF), diethylformamide, dimethylacetoamide (DMAc), N-methylpyrrolidone (NMP) or the like is used. As the nonionic surfactant, any of a polyoxyethylene base, a polyhydric alcohol fatty acid ester base, a base having both is used. The quantity of the nonionic surfactant to be added is generally 0.005-10% to attain sufficient dispersion effect.

CLAIMS

[Claim(s)]
[Claim 1]
A carbon nanotube dispersed solution which consists of a carbon nanotube, an amide system polar organic solvent, and a nonionic surfactant.
[Claim 2]
The carbon nanotube dispersed solution according to claim 1, wherein an amide system polar organic solvent is N-methyl pyrrolidone (NMP).
[Claim 3]
The carbon nanotube dispersed solution according to claim 1 or 2, wherein a nonionic surfactant is a polyoxyethylene system surface-active agent.
[Claim 4]
The carbon nanotube dispersed solution according to any one of claims 1 to 3, wherein an addition of a nonionic surfactant is 0.005 to 5%.
[Claim 5]
The carbon nanotube dispersed solution according to any one of claims 1 to 4, wherein a carborne nanotube is a monolayer carbon nanotube (SWNT).
[Claim 6]
The carbon nanotube dispersed solution according to any one of claims 1 to 5 characterized by including only a detailed carbon nanotube by filtering with a suspension particle diameter [m] of 0.1-3.0 micro as a carbon nanotube.
[Claim 7]
The carbon nanotube dispersed solution according to any one of claims 1 to 6 used for uniform dispersion of a carbon nanotube in polymer system nano composite.
[Claim 8]
The carbon nanotube dispersed solution according to any one of claims 1 to 7, wherein light scattering nature is decreasing.
[Claim 9]
A manufacturing method of a carbon nanotube dispersed solution carrying out mixture dispersion of the carbon nanotube to an amide system polar organic solvent and a non-ion system surface-active agent mixed solution ultrasonicating.
[Claim 10]
After carrying out mixture dispersion of the carbon nanotube to an amide system polar organic solvent and a non-ion system surface-active agent mixed solution, ultrasonicating, A manufacturing method of a carbon nanotube dispersed solution considering it as a solution which contains only a detailed carbon nanotube with a suspension particle diameter [m] of 0.1-3.0 micro by carrying out filtering.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
This invention relates to a carbon nanotube dispersed solution which added the nonionic surfactant to the amide system organic solvent, and a manufacturing method for the same. In particular, a carbon nanotube is related with a carbon nanotube distribution organic solvent for enabling application to various applications, such as polymer system nano composite, and a manufacturing method for the same.
[Background of the Invention]
[0002]
The discovered carbon nanotube is a tubular material of the thickness below the 1 micro m in diameter, the field of carbon 6 angle meshes of a net may form a pipe parallel to the axis of a tube as an ideal thing, and this pipe may become multiplex further in recent years. This carbon nanotube has the character which is made with carbon and changes with the number of 6 angle meshes of a net, and thickness of a tube, and its future is mechanical and it is expected as a functional material.
[0003]
It is useful to use the solvent in which the carbon nanotube was distributed uniformly using a carbon nanotube, such when mechanical and manufacturing functional material. For example, when a carbon nanotube melts polymer in the solvent distributed uniformly, the nano composite which the carbon nanotube distributed uniformly to the polymer matrix can be manufactured. A carbon nanotube can use as an optical instrument using the low dispersion nature which the solvent distributed uniformly has. It is used also when manufacturing an electronic device, electron emission devices, and rechargeable batteries, such as a transistor, by refining of dispersion liquid furthermore. For example, as a formation method of the emitter using carbon particles, the suspension which distributed carbon particles to the solvent was created, the solvent was dried and desired shape has been obtained, after forming the pattern of suspension on the support member which serves as a substrate using printing technique, such as the cast, screen-stencil, and an ink jet.
[0004]
Generally, as a solvent for carbon nanotube distribution, it is known that a water-soluble solvent, organic solvents, or those mixed solvents can be used. for example, water, an acidic solution, an alkaline solution, alcohol, ether, petroleum ether, benzene, ethyl acetate, chloroform, isopropyl alcohol, ethanol, acetone, toluene, etc. can be used -- the purport indication is carried out (refer to the following and the patent documents 1).
[0005]
However, the method of fully distributing a car BONNA tube to a solvent is not yet established. This is because it becomes the shape of a bunch, and funiculose with the cohesive force between carbon nanotubes (Van der Waals force). The smooth surface in the atom level of a carbon nanotube is a factor which falls the compatibility over a solvent. Therefore, in spite of character unique [a carbon nanotube] and useful, it is very difficult to manufacture the polymer

system nano composite etc. which distributed this uniformly, and application to the various application of a carbon nanotube is made into difficulty as a matter of fact.
[0006]
In order to improve the dispersibility over the solvent of a carbon nanotube, various trials are made until now, but sufficient effect has not necessarily been acquired.
[0007]
First, the method (refer to the following and the patent documents 2) of distributing a carbon nanotube in acetone is proposed, applying an ultrasonic wave. However, even if it can distribute while irradiating with the ultrasonic wave, after an exposure is completed, condensation of a carbon nanotube will start, and condensing, if the concentration of a car BONNA tube becomes high will break out.
[0008]
Next, using a surface-active agent is also proposed. although ultrasonicating as a surface-active agent using Tergitol(trademark) NP7 which is a non-ion system surface-active agent is proposed, if the loadings of a carbon nanotube are made to increase, a carbon nanotube will condense and uniform distribution will not be obtained -- the purport report is given. (Refer to the following nonpatent literature 1) **
By ultrasonicating ** and a monolayer nanotube in anionic detergent SDS solution, Although making the canal part of the hydrophobicity on the surface of a carbon nanotube and a surface-active agent adsorb, forming a hydrophilic part outside, and distributing in solution is also reported (refer to the following nonpatent literature 2), since it is a water-soluble solvent, For example, when applying to polymer system nano composite, applicable polymers will be restricted to a water soluble polymer, and a limit is located in an application range. Although similarly the method of attaching the canal portion of water soluble polymer PVP on the surface of a carbon nanotube instead of a surface-active agent is also proposed, it is a water soluble polymer too and the application range is restricted (refer to the following nonpatent literature 3).
[Patent documents 1] JP,2000-72422,A
[Patent documents 2] JP,2000-86219,A
[Nonpatent literature 1] S.Cui et al. Carbon 41,2003,797-809
[Nonpatent literature 2] Michael J. O'Connel et al. SCIENCE VOL297 26 July 2002,593-596
[Nonpatent literature 3] Michael J. O'Connel et al. CHEMICALPHYSICS LETTERS,13 July 2001, 264-271
[Description of the Invention]
[Problem(s) to be Solved by the Invention]
[0009]
If the solvent which distributed the carbon nanotube uniformly is used, it is applicable to various uses using the unique character of a carbon nanotube, but it is difficult to obtain the solvent distributed uniformly from the low level of the cohesive force between carbon nanotubes, and surface affinity. Although distribution of the carbon nanotube to the polar organic solvent currently especially used abundantly as a solvent of polymer on the occasion of the application to polymer system nano composite etc. is very useful, it has not succeeded in making it distribute to such a polar organic solvent effectively until now.
[0010]
Therefore, the purpose of this invention is to provide the method that a polar organic solvent useful as a polymer solvent can be made to distribute a carbon nanotube effectively.
[Means for Solving the Problem]
[0011]
This invention paying one's attention to a function as a dispersing agent to a carbon nanotube of a nonionic surfactant. It finds out exhibiting an amide system polar organic solvent and a function as a dispersing agent in which it excelled when it was made to dissolve, irradiating NMP (N methyl pyrrolidone) with an ultrasonic wave especially for a nonionic surfactant. Application to an optical instrument which could provide a method very advantageous to manufacture of polymer system nano composite using a carbon nanotube, and used reduction of light scattering by this, etc. are attained.

[0012]
Specifically, this invention consists of the next composition.
(1) A carbon nanotube dispersed solution which consists of a carbon nanotube, an amide system polar organic solvent, and a nonionic surfactant.
(2) A carbon nanotube dispersed solution given in the above (1), wherein an amide system polar organic solvent is N-methyl pyrrolidone (NMP).
(3) The above (1), wherein a nonionic surfactant is a polyoxyethylene system surface-active agent, or a carbon nanotube dispersed solution given in (2).
(4) A carbon nanotube dispersed solution given in either of aforementioned (1) - (3), wherein a blending ratio of a nonionic surface active agent is 0.005 to 5%.
(5) A carbon nanotube dispersed solution given in either of aforementioned (1) - (4), wherein a carborne nanotube is a monolayer carbon nanotube (SWNT).
(6) A carbon nanotube dispersed solution given in either of aforementioned (1) - (5) by which only a detailed carbon nanotube being included as a carbon nanotube by processing with a filter with a suspension particle diameter [m] of 0.1-3.0 micro.
(7) A carbon nanotube dispersed solution given in either of aforementioned (1) - (6) used for uniform dispersion of a carbon nanotube in polymer system nano composite.
(8) A carbon nanotube dispersed solution given in either of aforementioned (1) - (7), wherein light scattering nature is decreasing.
(9) A manufacturing method of a carbon nanotube dispersed solution carrying out mixture dispersion of the carbon nanotube to an amide system polar organic solvent and a non-ion system surface-active agent mixed solution ultrasonicating.
(10) To an amide system polar organic solvent and a non-ion system surface-active agent mixed solution. A manufacturing method of a carbon nanotube dispersed solution considering it as a solution which contains only a detailed carbon nanotube by processing with a filter with a suspension particle diameter [m] of 0.1-3.0 micro after carrying out mixture dispersion of the carbon nanotube, ultrasonicating.
[0013]
As an amide system polar organic solvent used by this invention, although both dimethylformamide (DMF) a diethylformamide dimethylacetamide (DMAc) N-methyl pyrrolidone (NMP), etc. can be used, specifically, It is good to use N-methyl pyrrolidone (NMP) preferably especially. These can be lent in many organic matters (except for low grade hydrocarbon), an inorganic substance, polar gas and polymers especially polyamide, polyimide, polyester, polyurethane, and an acrylic resin. Therefore, if a carbon nanotube can be uniformly distributed to these solvents, polymer system nano composite which a carbon nanotube distributed uniformly can be obtained by lending the dispersion liquid in these polymer materials.
[0014]
Although it may be any of a polyoxyethylene system, polyhydric alcohol and a fatty-acid-ester system, and a system having these both as a nonionic surfactant used by this invention, a thing of a polyoxyethylene system is used especially preferably. As an example of a polyoxyethylene system surface-active agent, Polyoxyethylene ether of fatty acid, polyoxyethylene ether of higher alcohol, There are ARUKIRORUAMAIDO of alkylphenol polyoxyethylene ether, polyoxy NICHIREN ether of sorbitan ester, polyoxyethylene ether of castor oil, polyoxyethylene ether of polyoxypropylene, and fatty acid, etc. As an example of polyhydric alcohol and a fatty-acid-ester system surface-active agent, there are a mono- glycerite type surface-active agent, a sorbitol type surface-active agent, a Salter mold surface-active agent, a sugar ester type surface-active agent, etc.
[0015]
Although it can set suitably according to loadings of a carbon nanotube, and a kind of amide system polar organic solvent to blend, if an addition of these nonionic surfactants is 0.005 to 10%, generally it can acquire sufficient dispersion effect of a carbon nanotube. Since quantity of a surface-active agent [as opposed to / that it is 0.005% or less / a carbon nanotube] runs short, some nanotubes will be condensed and a sediment will produce them. Since molecular rotation in inside of a solvent of surfactant molecules becomes it difficult that it is not less than

10%, it becomes impossible to adsorb a canal part of a surface-active agent of sufficient quantity for the hydrophobic nanotube surface, and is inconvenient to distribution of a detailed nanotube. When loadings of a carbon nanotube are made 0.005 to 0.05%, 0.01 to 5% of loadings of a nonionic surfactant are good.

[0016]

According to the purpose, it can use for a carbon nanotube used by this invention, respectively from a multilayer thing (referred to as a multiwall carbon nanotube and "MWNT") to a thing (referred to as a single wall carbon nanotube and "SWNT") of a monolayer. In this invention, a single wall carbon nanotube is used preferably. Especially as a manufacturing method of SWNT to be used, it is not what is restricted, Adoption **** does not care about which conventionally publicly known manufacturing methods, such as a thermal decomposition method (a method similar to vapor phase growth) using a catalyst, arc discharge process, a laser vaporization method, and the HiPco method (High-pressure carbon monoxide process), either.

[0017]

Below, it illustrates by laser evaporation about the technique of creating a suitable single wall carbon nanotube for this invention. As a raw material, graphite powder, and nickel and a cobalt impalpable powder mixing rod were prepared. This mixed rod Under 665 hPa (500Torr) argon atmosphere, It heated at 1,250 ** with an electric furnace, and irradiated there with a second-harmonic pulse of Nd:YAG laser of 350 mJ/Pulse, and a single wall carbon nanotube was produced by evaporating carbon and metal particles.

[0018]

The above manufacturing method is a classic example to the last, and even if it changes a metaled kind, a kind of gas, temperature of an electric furnace, wavelength of laser, etc., it does not interfere. A method of producing other than laser evaporation, for example, the HiPco method, a CVD method, It does not interfere, even if it uses a single wall nanotube produced by other techniques, such as arc discharge process, a thermal decomposition method of carbon monoxide, the template method that inserts and carries out the pyrolysis of the organic molecule into a detailed hole, fullerene, metal vapor codeposition.

[0019]

Although it changes also with purposes of use, loadings of a carbon nanotube are not limited especially as long as dispersibility is acquired. SWNT is used and they are NMP and polyoxy ECHIRE.

When it distributes to a mixed solution of a surface-active agent of a N system, it can distribute a maximum of 0.05%. It is good 0.005 to 0.05% of especially preferably.

[0020]

Although the ultrasonic wave used by this invention was able to acquire a good dispersion effect by taking about 1 time processing using 20 kHz, 150W and 28 kHz, and 140W, conditions of an ultrasonic wave of this invention are not limited to this. It is possible to set suitably according to quantity of a carbon nanotube blended, a kind of amide system polar organic solvent, etc.

[0021]

As for a filter used by this invention, a glass fiber filter, a membrane filter, etc. are used. In that case, suspension particle diameter of a filter can be suitably defined according to the purpose. Although it asks for barium sulfate etc. which were specified as suspension particle diameter by JIS 3801 with disclosure particle diameter when it filters automatically, substantially, it is equivalent to an average pore size of a filter. For example, when applying to an optical instrument using reduction of light scattering, suspension particle diameter of a filter is so good that it is small, but generally a thing with a suspension particle diameter [m] of 0.1-3.0 micro can be used.

[Effect of the Invention]

[0022]

According to this invention, a nonionic surfactant and an amide system polar organic solvent, and the dispersing solvent that the carbon nanotube distributed uniformly when it was made to dissolve in it especially, irradiating a NMP (N methyl pyrrolidone) mixed solution with an ultrasonic wave can obtain a carbon nanotube. As it can come, it receives and it is shown in the

following examples, unless it adds a surface-active agent, even if it uses a NMP solution, a carbon nanotube cannot be condensed and cannot be distributed uniformly. Even if it uses polar solvents other than this invention, and the mixed solution of a surface-active agent, it is difficult to condense a carbon nanotube and to make it distribute effectively.

[0023]

Thus, by using for an amide system polar organic solvent the solution which added the non-ion system surface-active agent, it can distribute uniformly, without a carbon nanotube condensing, and this invention becomes applicable to various fields of carbon nanotube material.

[Best Mode of Carrying Out the Invention]

[0024]

By making it distribute, irradiating with an ultrasonic wave the NMP solution which added 0.01 to 5% of the polyoxyethylene system surface-active agent for 0.005 to 0.05% of the monolayer carbon nanotube, as shown in the following examples, The polar organic solvent which was extremely excellent in the dispersibility of a carbon nanotube can be obtained.

[0025]

(Example 1)

SWNT (1 mg) manufactured by the HiPco method (high voltage carbon monoxide method), When it put into the NMP (N-methyl pyrrolidone) solvent 10g and the mixed solvent of Triton (trademark)X-100 (10 mg) which is a polyoxyethylene system surface-active agent, it mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0026]

Next, divide this carbon nanotube dispersed solution into two, and it filters with the separation (it is 2 hours at 190,000 g) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm) by an ultracentrifuge, respectively, With the liquid processed by ultra-centrifugal separation, with the liquid which filtered whether supernatant liquid was black with glass fiber filter paper, when it investigated whether filtrate would be black, it both turned out that it is black.

[0027]

(Example 2)

The kind of surface-active agent was changed and the same process as Example 1 was performed. SWNT (1 mg) manufactured by the HiPco method (high voltage carbon monoxide method), When it put into the NMP (N-methyl pyrrolidone) solvent 10g and the mixed solvent of Triton(trademark) N-101 and Reduced (10 mg) which are polyoxyethylene system surface-active agents, it mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0028]

Next, divide this carbon nanotube dispersed solution into two, and it filters with the separation (it is 2 hours at 190,000 g) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm) by an ultracentrifuge, respectively, With the liquid processed by ultra-centrifugal separation, with the liquid which filtered whether supernatant liquid was black with glass fiber filter paper, when it investigated whether filtrate would be black, it both turned out that it is black.

[0029]

(Example 3)

The kind of surface-active agent was changed and the same process as Example 1 was performed. SWNT (1 mg) manufactured by the HiPco method (high voltage carbon monoxide method), When it put into the NMP (N-methyl pyrrolidone) solvent 10g and the mixed solvent of Igepal(trademark) CA210 (10 mg) which is a polyoxyethylene system surface-active agent, it mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0030]

Next, divide this carbon nanotube dispersed solution into two, and it filters with the separation (it is 2 hours at 190,000 g) and glass fiber filter paper (GC-50 and suspension particle diameter

0.5microm) by an ultracentrifuge, respectively, With the liquid processed by ultra-centrifugal separation, with the liquid which filtered whether supernatant liquid was black with glass fiber filter paper, when it investigated whether filtrate would be black, it both turned out that it is black.

[0031]

(Example 4)

The kind of surface-active agent was changed and the same process as Example 1 was performed. SWNT (1 mg) manufactured by the HiPco method (high voltage carbon monoxide method), When it put into the NMP (N-methyl pyrrolidone) solvent 10g and the mixed solvent of Tween(trademark)60 (10 mg) which is a polyoxyethylene system surface-active agent, it mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0032]

Next, divide this carbon nanotube dispersed solution into two, and it filters with the separation (it is 2 hours at 190,000 g) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm) by an ultracentrifuge, respectively, With the liquid processed by ultra-centrifugal separation, with the liquid which filtered whether supernatant liquid was black with glass fiber filter paper, when it investigated whether filtrate would be black, it both turned out that it is black.

[0033]

(Example 5)

The kind of surface-active agent was changed and the same process as Example 1 was performed. SWNT (1 mg) manufactured by the HiPco method (high voltage carbon monoxide method), When it put into the NMP (N-methyl pyrrolidone) solvent 10g and the mixed solvent of Brij(trademark)58 (10 mg) which is a polyoxyethylene system surface-active agent, it mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0034]

Next, divide this carbon nanotube dispersed solution into two, and it filters with the separation (it is 2 hours at 190,000 g) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm) by an ultracentrifuge, respectively, With the liquid processed by ultra-centrifugal separation, with the liquid which filtered whether supernatant liquid was black with glass fiber filter paper, when it investigated whether filtrate would be black, it both turned out that it is black.

[0035]

(Example 6)

The concentration of the surface-active agent was changed and the same process as Example 1 was performed. Triton(trademark)X-100 which is a polyoxyethylene system surface-active agent to the NMP (N-methyl pyrrolidone) solvent 10g 1 mg, 5 mg, 50 mg, 100 mg, 500 mg, 1000 mg, 1500 mg, When the mixed solution added 2000 mg was prepared, SWNT (1 mg) manufactured by each by the HiPco method (high voltage carbon monoxide method) was mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0036]

Next, when these carbon nanotube dispersed solutions are filtered with glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm), and it investigates whether filtrate is black, and the additions of a surface-active agent are 1 mg, 5 mg, 50 mg, 100 mg, and 500 mg, it is black, but. In the case of 1000 mg, 1500 mg, and 2000 mg, it turned out that it is almost transparence.

[0037]

(Example 7)

The kind of solvent was changed and the same process as Example 1 was performed. SWNT (1 mg) manufactured by the HiPco method (high voltage carbon monoxide method), When it put into the DMAc (dimethylacetamide) solvent 10g and the mixed solvent of Triton(trademark)X-100 (10

mg) which is a polyoxyethylene system surface-active agent, it mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0038]

Next, divide this carbon nanotube dispersed solution into two, and it filters with glass fiber filter paper (GA-100 and suspension particle diameter 1.0microm) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm), When it investigated whether filtrate would be black, in the case of GA-100, it is black, and it turned out that that it is and is black says in the case of GC-50.

[0039]

(Example 8)

The kind of solvent was changed and the same process as Example 1 was performed. SWNT (1 mg) manufactured by the HiPco method (high voltage carbon monoxide method), When it put into the DMF (dimethylformamide) solvent 10g and the mixed solvent of Triton(trademark)X-100 (10 mg) which is a polyoxyethylene system surface-active agent, it mixed and 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0040]

Next, divide this carbon nanotube dispersed solution into two, and it filters with glass fiber filter paper (GA-100 and suspension particle diameter 1.0microm) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm), When it investigated whether filtrate would be black, in the case of GA-100, it is light black, and, in the case of GC-50, it turned out that it is almost transparence.

[0041]

(Example 9)

The carbon nanotube manufactured by laser evaporation performed the same process as Example 1. Put SWNT (1 mg) manufactured by laser evaporation into the NMP (N-methyl pyrrolidone) solvent 10g and the mixed solvent of Triton(trademark)X-100 (10 mg) which is a polyoxyethylene system surface-active agent, and it mixes, When 1 time processing was carried out ultrasonically (20 kHz), it became liquid of muddy black and the precipitate was not formed.

[0042]

Next, divide this carbon nanotube dispersed solution into two, and it filters with the separation (it is 2 hours at 190,000 g) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm) by an ultracentrifuge, respectively, With the liquid processed by ultra-centrifugal separation, with the liquid which filtered whether supernatant liquid was black with glass fiber filter paper, when it investigated whether filtrate would be black, it both turned out that it is black.

[0043]

(Example 10)

The carbon nanotube dispersed solution obtained in Examples 1 and 2 was mixed in the NMP solution of block copolymerization polyimide, and the NMP solution of the polyvinyl pyrrolidone, respectively, and the thin film was formed with the doctor blade method. The floc of the nanotube was not observed when each thin film was observed with the optical microscope. About the latter thin film, when micro Raman measurement, and visible and near infrared absorption-spectrum measurement were performed, the Raman signal and optical absorption of the nanotube were detected.

[0044]

Thus, it has checked that SWNT could be uniformly distributed to polymer by using the carbon nanotube dispersed solution obtained by this invention.

[0045]

(Example 11)

When the light scattering nature of the carbon nanotube dispersed solution obtained in Examples 1 and 9 was checked with the dynamic-light-scattering measuring device, it has checked having very low light scattering nature.

[0046]
(Comparative example 1)
The same process as Example 1 was performed without using a surface-active agent. When it put into the NMP (N-methyl pyrrolidone) solvent 10g, it mixed and 1 time processing of the SWNT (1 mg) manufactured by the HiPco method was carried out ultrasonically (20 kHz), although the liquid of muddy black was obtained, precipitate of a carbon nanotube adhered to the glassware wall surface.
[0047]
Next, divide into two the carbon nanotube dispersed solution which carried out muddy black, and it filters with glass fiber filter paper (GA-100 and suspension particle diameter 1.0microm) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm), When it investigated whether filtrate would be black, it both turned out that it is transparent.
[0048]
(Comparative example 2)
The same process as Example 6 was performed without using a surface-active agent. When it put into the DMAc (dimethylacetamide) solvent 10g, it mixed and 1 time processing of the SWNT (1 mg) manufactured by the HiPco method was carried out ultrasonically (20 kHz), although the liquid of muddy black was obtained, precipitate of a carbon nanotube adhered to the glassware wall surface.
[0049]
Next, divide into two the carbon nanotube dispersed solution which carried out muddy black, and it filters with glass fiber filter paper (GA-100 and suspension particle diameter 1.0microm) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm), When it investigated whether filtrate would be black, it both turned out that it is transparent.
[0050]
(Comparative example 3)
The same process as Example 7 was performed without using a surface-active agent. When it put into the DMF (dimethylformamide) solvent 10g, it mixed and 1 time processing of the SWNT (1 mg) manufactured by the HiPco method was carried out ultrasonically (20 kHz), although the liquid of muddy black was obtained, precipitate of a carbon nanotube adhered to the glassware wall surface.
[0051]
Next, divide into two the carbon nanotube dispersed solution which carried out muddy black, and it filters with glass fiber filter paper (GA-100 and suspension particle diameter 1.0microm) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm), When it investigated whether filtrate would be black, it both turned out that it is transparent.
[0052]
(Comparative example 4)
Put SWNT (1 mg) into the acetone 10g and the acetone 10g, and each mixed solvent of Triton (trademark)X-100 (10 mg) which is a polyoxyethylene system surface-active agent, and it mixes, When 1 time processing was carried out ultrasonically (20 kHz), the sediment which both did not do [the sediment] muddy black but the carbon nanotube condensed produced the solution after the end of ultrasonication.
[0053]
(Comparative example 5)
Put SWNT (1 mg) into the dimethyl sulfoxide 10g and the dimethyl sulfoxide 10g, and each mixed solvent of Triton(trademark)X-100 (10 mg) which is a polyoxyethylene system surface-active agent, and it mixes, When 1 time processing was carried out ultrasonically (20 kHz), the sediment which both did not do [the sediment] muddy black but the carbon nanotube condensed produced the solution after the end of ultrasonication.
[0054]
(Comparative example 6)
Put SWNT (1 mg) into each mixed solvent of Triton(trademark)X-100 (10 mg) which is 10g of 2-propanol and 10 g of 2-propanol, and a polyoxyethylene system surface-active agent, and it

mixes, When 1 time processing was carried out ultrasonically (20 kHz), the sediment which both did not do [the sediment] muddy black but the carbon nanotube condensed produced the solution after the end of ultrasonication.
[0055]
(Comparative example 7)
Put SWNT (1 mg) into the gamma-butyrolactone 10g and the gamma-butyrolactone 10g, and each mixed solvent of Triton(trademark)X-100 (10 mg) which is a polyoxyethylene system surface-active agent, and it mixes, When 1 time processing was carried out ultrasonically (20 kHz), the sediment which the carbon nanotube condensed produced the former and the latter became muddy black liquid mostly.
[0056]
Next, divide the latter carbon nanotube dispersed solution into two, and it filters with glass fiber filter paper (GA-100 and suspension particle diameter 1.0microm) and glass fiber filter paper (GC-50 and suspension particle diameter 0.5microm), When it investigated whether filtrate would be black, it both turned out that it is transparent.
[0057]
(Comparative example 8)
The same process as Example 9 was performed without using a surface-active agent. The carbon nanotube distribution NMP solution which does not contain the surface-active agent obtained by the comparative example 1 was mixed in the NMP solution of block copolymerization polyimide, and the NMP solution of the polyvinyl pyrrolidone, and the thin film was formed with the doctor blade method. When each thin film was observed with the optical microscope, formation of the floc of the nanotube accompanying the phase separation of polymer and a nanotube was observed.
[Industrial applicability]
[0058]
this invention, since the polar organic solvent which the carbon nanotube distributed uniformly can be provided, Manufacture of the carbon nanotube material to various uses, such as manufacture of the polymer system nano composite using a carbon nanotube, application to the optical instrument using reduction of light scattering, and manufacture of the device for electron emission, is attained.

[Translation done.]